SOIL CONDITION AS INFLUENCED BY CROPPING AND TILLAGE SYSTEMS IN THE CENTRAL HIGH PLAINS

J.R. Fortner, USDA-NRCS
J.W. Doran & T. Kettler, USDA-ARS
W.L. Powers, Univ. of Nebraska

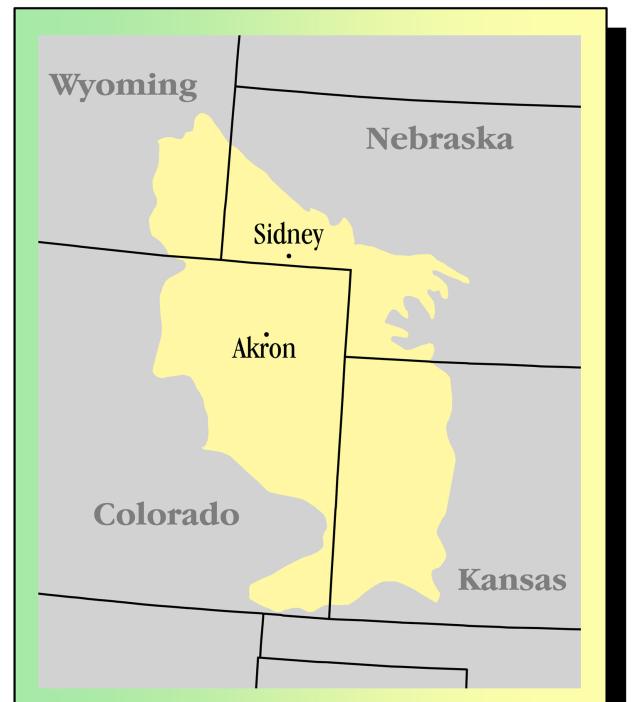


Figure 1. Geographic location of the study area.

Table 1. Study area characteristics.

	Akron, CO	Sidney, NE
Latitude	40° 09.50'N	41° 15.55'N
Longitude	103° 08.40'W	103° 00.65'W
Soil Type	Weld silt loam	Duroc loam
Classification	fine, smectitic, mesic, Aridic Argiustolls	fine-silty, mixed, mesic, Pachic Haplustolls
MAP (mm)	419	446
MAAT (°C)	8.9	9.3
Plot size (m)	9.2 x 30.5	8.5 x 45.5
Slope	< 1%	< 0.5%
Plots Established	1990	1969
Fertilized ?	Yes	No

Table 2. Percent reduction of infiltration rates by wheel track compaction.

	Akron	Sidney
NTWF	50	80
CTWF	95	96
RTWF	---	93
RTWMSF	50	---
NTWCM	80	---

Figure 2. Research plots at Sidney, Nebraska.

ABSTRACT

Winter wheat (*Triticum aestivum* L.)-fallow cropping systems are used in the semi-arid U.S. Central High Plains to overcome the impact of erratic rainfall on grain production. Alternative systems with various frequencies and kinds of tillage and utilizing other crops and longer rotations have been tried. The purpose of this research was to evaluate the impacts on soil properties by various cropping and tillage systems. Tests were conducted near Sidney, Nebraska, and Akron, Colorado. Soil quality indicators evaluated include: infiltration rate, bulk density, organic matter content, pH, electrical conductivity (EC), total and inorganic nitrogen, and particle size distribution. Evaluating wheel-tracked and non-tracked interrows tested the effects of compaction. Results indicate that type and frequency of tillage and cropping systems do affect some soil quality indicators. Conventional-till (CT) systems had slower intake rates, higher bulk density, and less organic matter than reduced-till (RT) and no-till (NT) systems in the surface 7.5 cm. Wheel-track areas tended to have increased bulk density and reduced infiltration rates. Soil pH at Akron indicates that inefficient use of fertilizer N is resulting in soil acidification and possible leaching of NO_3-N to groundwater supplies.

BACKGROUND

The semi-arid U.S. Central High Plains region of eastern Colorado, western Kansas, western Nebraska, and eastern Wyoming (Figure 1) is characterized by rainfall of marginal quantity to support annual cropping systems. Rainfall in the region is generally less than 500 mm per year. Rainfall during the growing season often occurs as short-duration, high-intensity events that can result in significant runoff and accompanying soil erosion.

Winter wheat (*Triticum aestivum* L.)-fallow cropping systems have long been the standard to overcome or minimize the impact of erratic rainfall on grain production. During the 14-month fallow period the soil accumulates water to be used during the following crop year. The intent is that the stored water plus rainfall received during the crop year will be adequate to produce the crop. Protecting the soil from wind and water erosion and controlling weed populations during the fallow period are significant management concerns. Weed growth during the fallow period draws on the stored water intended for the upcoming crop year.

In recent years, alternatives to this cropping system, including various levels and kinds of tillage throughout the rotation period, have been used to reduce erosion hazards and to control weed populations. Other modifications to the wheat-fallow system include adopting a longer rotation system and utilizing other crops such as corn (*Zea mays* L.), proso millet (*Panicum miliaceum* L.), and sunflower (*Helianthus annus* L.). By doing so, producers reduce the frequency of the fallow period to every third, fourth, or fifth year. Initial studies indicate these systems significantly increase total crop production over the time-span of the rotation when compared to wheat-fallow (Anderson, et al., 1999).

Many soil properties are considered to be use- and time-dependent in that they have different values depending on the land-use and the time of the year or stage of the cropping cycle. Tillage makes several obvious modifications to the soil physical environment. Soil properties commonly modified by tillage include soil structure, bulk density, porosity, infiltration rates, organic carbon content and distribution, nutrient distribution, and (to some extent) particle size distribution (Logan, et al., 1991). Other properties or factors affected include pore size distribution, soil structure or aggregate size and shape, and crop residue placement. These factors further impact various soil chemical, physical, and biological properties such as soil microbial activity, water movement and water storage capacity, soil temperature, and nutrient distribution.

There are some preliminary data that indicate possible negative impacts with some management systems, such as increased soil bulk density, reduced infiltration rates, modification of organic matter contents of Ap horizons, and increased soil acidification (Doran, 1997). Results of research studying the effects of management systems on soil properties in other regions of the country are inconclusive and often contradictory.

RESEARCH OBJECTIVE

To assess the impacts of tillage management systems, cropping systems, and compaction due to wheel traffic on soil quality indicators at Akron, Colorado, and Sidney, Nebraska.

STUDY AREA

Two sites were chosen for evaluation. One at the USDA-ARS Central Great Plains Research Station, near Akron, Colorado; and a second at the High Plains Agricultural Laboratory, near Sidney, Nebraska. Both locations have established research plots with different tillage systems in place and, in the case of Akron, have different crop rotations. Table 1 lists some characteristics of these sites.

Figure 5. Second Increment Infiltration Rates - Akron 1997

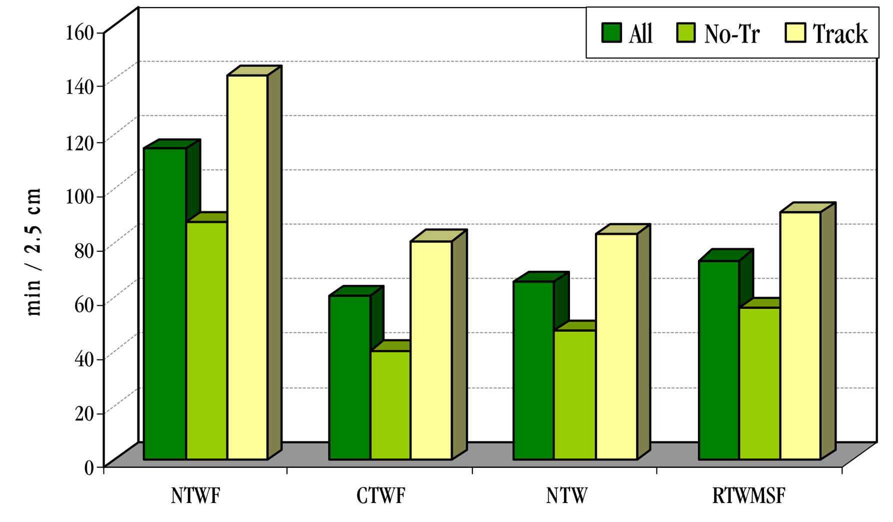


Figure 6. Second Increment Infiltration Rates - Sidney 1997

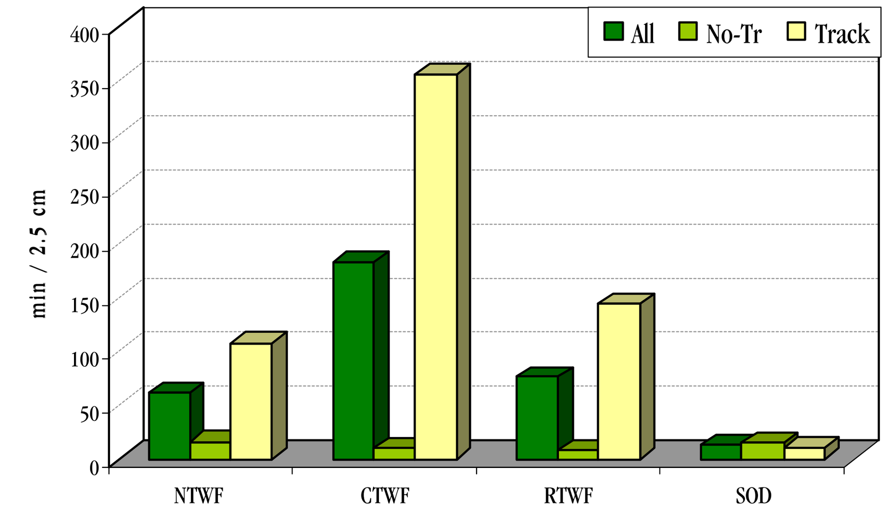


Figure 7. Bulk Density (0-7.5 cm) - Akron 1997

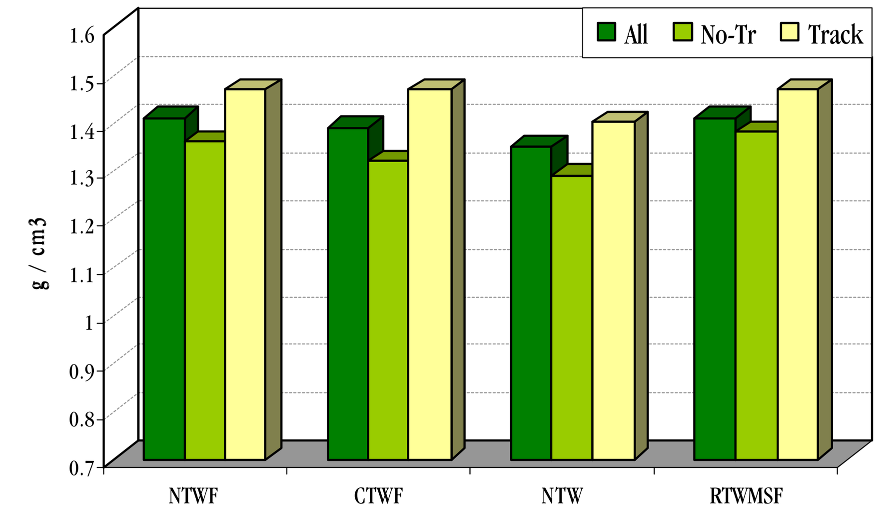


Figure 8. Bulk Density (0-7.5 cm) - Sidney 1997

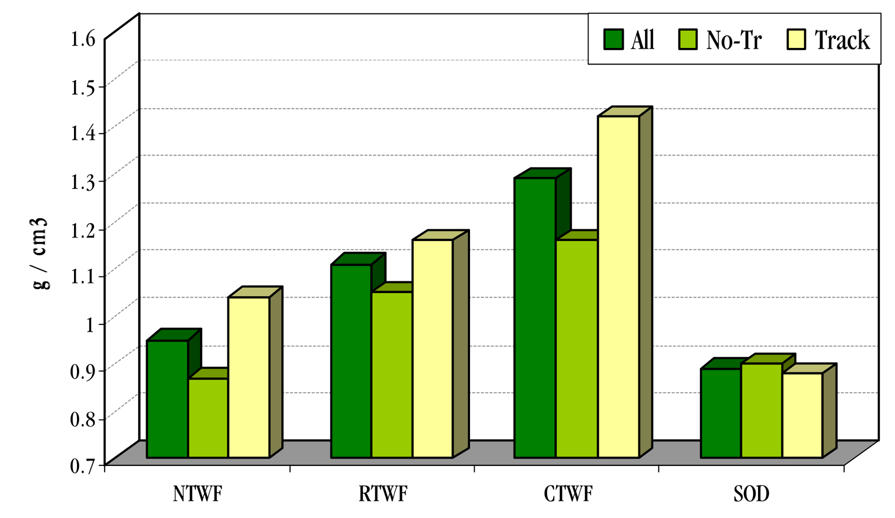


Figure 9. Total Soil OM by Depth - Akron 1997

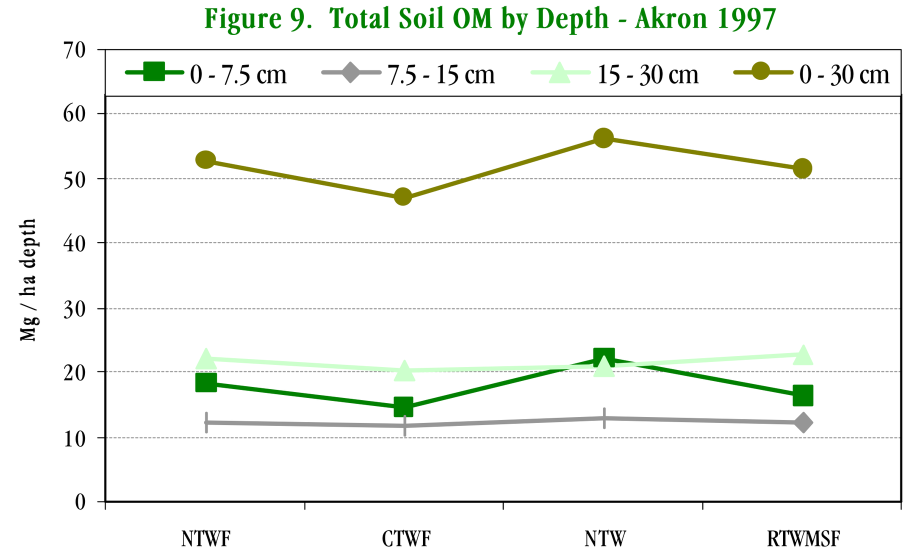


Figure 10. Total Soil OM by Depth - Sidney 1997

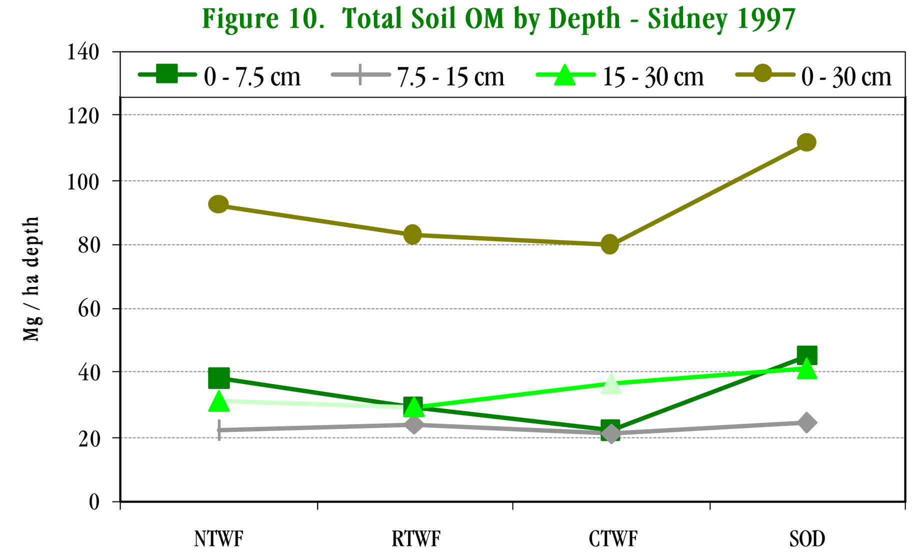


Figure 11. Soil pH - Akron 1997

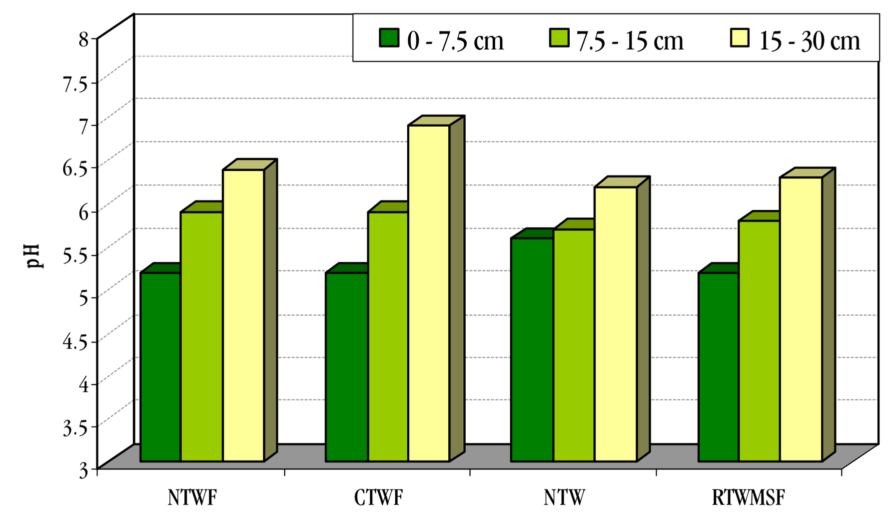
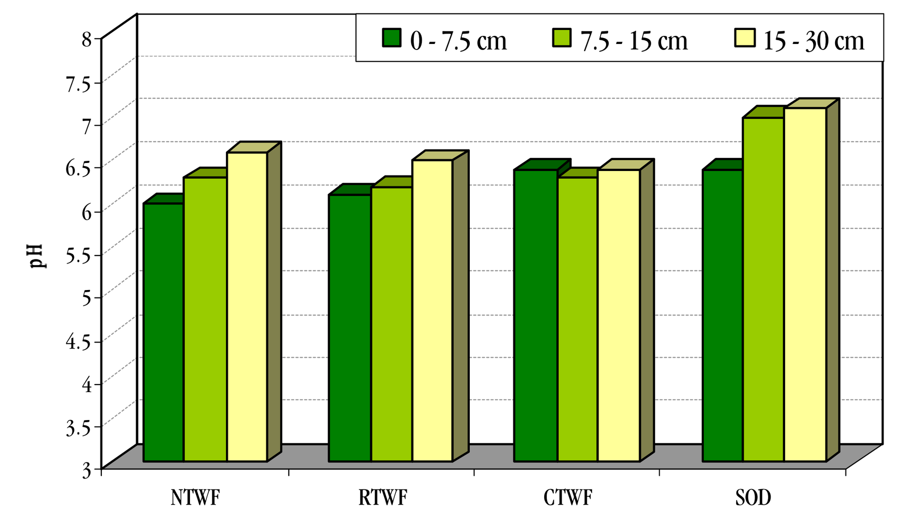


Figure 12. Soil pH - Sidney 1997



METHODS and MATERIALS

Treatments chosen for the study at Sidney were no-till wheat fallow (NTWF), reduced-till wheat fallow (RTWF), conventional-till wheat fallow (CTWF), and SOD (Figure 2). At Akron, treatments chosen were no-till wheat fallow (NTWF), no-till continuous wheat (NTW), conventional till wheat fallow (CTWF), and a reduced-till wheat-millet-sunflower-fallow rotation (RTWMSF). In 1998, a fifth plot -- no-till wheat-corn-millet (NTWCM) rotation -- was also sampled at Akron.

Six observation points within each plot were located -- three in the non-tracked interrow and three in the tractor-tracked interrow (Figure 3 and Figure 4). Data were collected in 1997 and 1998 at both locations. In 1997, data collection was after wheat harvest and before any tillage operations occurred -- July 21-22 at Akron, and August 13-14 at Sidney. In 1998, soil samples and field data were collected July 22-23 at Akron, and July 23-24 at Sidney.

Water infiltration rates were measured using a single-ring infiltrometer, which consisted of a section of aluminum irrigation pipe (15-cm inside diameter) that was driven into the soil to a depth of 7.5 cm. Infiltration times for two 2.5-cm increments of deionized water were recorded.

Samples for soil property analyses were collected using an Oakfield push probe fitted with dry tips (1.91-cm inside diameter). In 1997, soil samples were collected from depths of 0 to 3.8, 3.8 to 7.6, 7.6 to 15.2, and 15.2 to 30.5 cm. For simplicity, these depths are referred to as the 0 to 3.8, 3.8 to 7.5, 7.5 to 15, and 15 to 30 cm increments. In 1998, samples were collected from the 0 to 7.6, 7.6 to 15.2, and 15.2 to 30.5 cm depths. These depths will be referred to as 0 to 7.5, 7.5 to 15, and 15 to 30 cm. The push probe cores were collected just outside the infiltration rings in line with the track or no-track interrow orientation. Depth increments from six insertions of the sampler were composited at each sample point to collect an adequate volume of soil for analysis.

Samples for bulk density determination of the 0 to 7.5 cm layer were collected by driving a 7.6-cm inside diameter aluminum irrigation pipe into the soil to a depth of 7.5 cm.

Processing of the samples in the laboratory began with each sample being weighed for total mass, sub-sampled for gravimetric water content, and then passed through a 2-mm sieve. In 1997, the soil quality parameters (indicators) measured were bulk density, inorganic nitrogen (NO_3^- and NH_4^+), total nitrogen, total and organic carbon, electrical conductivity (EC) and pH. In 1998, the parameters measured were bulk density, inorganic nitrogen (NO_3^- and NH_4^+), EC, pH, total organic matter by loss on ignition, and particulate organic matter by loss on ignition. Particle size distribution was measured on selected samples in 1997, and sand content was estimated in 1998. Standard laboratory methods were used for each analysis.

RESULTS

Results for soil analyses of organic carbon, total nitrogen, inorganic nitrogen, total soil organic matter (SOM), and particulate organic matter (POM) were converted from a mass basis (percent by weight for organic carbon and total nitrogen, mg g^{-1} for inorganic nitrogen, mg g^{-1} for POM and SOM) to a volumetric basis (kg or Mg ha^{-1} depth). Statistical significance was evaluated at the $\alpha = 0.05$ level. Results are shown only for 1997. Results from 1998 followed similar trends.

CONCLUSIONS

The type and frequency of tillage and cropping systems significantly affect some soil properties, and compaction by wheel traffic affects infiltration rates and bulk density. Water infiltration rate was affected by the type of tillage system with CT < RT and NT (Figure 5 and Figure 6). Compaction may be an overriding factor as there was a 50 to 95 percent reduction in infiltration rates by wheel traffic (Table 2). The compaction effect varied by tillage system. Infiltration rates are at a level that rainfall exceeding 5 cm in two hours is likely to produce runoff every 5 to 10 years from CTWF systems at Sidney, and from NTWF and NTWCM systems at Akron, increasing the risk of soil erosion.

Bulk density in the 0 to 7.5 cm layer was affected at Sidney with NT < RT < CT (Figure 7 and Figure 8). Values at Akron showed little variation.

Total soil organic matter and particulate organic matter levels were affected by tillage system with NT > CT in 0 to 7.5 cm layer (Figure 9 and Figure 10). Organic matter in CT was more evenly distributed throughout the upper 30 cm than in RT or NT.

Soil pH was affected by tillage system with NT < CT in the 0 to 7.5 and 15 to 30 cm layers (Figure 11 and Figure 12). This is an indication of increased soil acidification, loss of CO_2 from calcareous soils, inefficient use of fertilizer N, and potential leaching of NO_3-N to groundwater supplies. To avoid such concerns there is a need to balance application rates of fertilizer N with expected plant use.

The effects varied with tillage system and the timing of measurement indicating that no one system is superior to another in all aspects and that no matter which system is used, soil condition/quality must be monitored.

Figure 3. No-till wheat-fallow plot at Akron, Colorado, showing infiltration rings at observation points -- 3 in wheel-tracked and 3 in non-tracked areas.

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ACKNOWLEGEMENTS

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Figure 4. Infiltration ring in sod plot at Sidney site.